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ENERGY DISSIPATION CHARACTERISTICS IN TISSUE FOR IONIZING RADIATION IN SPACE

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As announced in the preceding Progress Report (No. 17), a joint NASA-NAMI Report, NAMI-987, "Linear Energy Transfer Spectra and Dose Equivalents of Galactic Rudiation Exposure in Space" has been distributed. Its essential findings have been presented at the Annual Meeting of the Aerospace Medical Association in Washington on April 12, 1967.

Work has continued in a direction that proceeds, from the LET distribution of the primary galactic radiation as analyzed in NAMI-987, to the transition that occurs as the radiation travels in absorbing material. It proved advantageous to break down the computational analysis in two parts. The first one pertains exclusively to the residual primary flux and its LET spectrum at different depths whereas the second one follows up the fate of the energy removed from the primary beam in nuclear collisions. It is easily seen that the first task is much simpler than the second. Dosimetrically, main importance rests on the first part since it concerns that fraction of the total energy dissipation for which no degrading of the LET occurs, i.e., the biologically most effective part.

In view of the unusually large computational workload involved in a complete analysis of all Z numbers of the heavy spectrum, the Ne component ($Z = 10$, $A = 20$) was selected as a representative medium heavy nucleus for the first phase of the program in which the basic computational procedure was to be developed. At this time, the analysis of the transition of the primary flux for the Ne component is completed. One feature of the results is of special interest. Since the differential energy spectrum of the incident radiation has a pronounced broad maximum at a comparatively high energy, i.e., a positive slope over a sizeable interval at low energies, the low energy flux initially increases with increasing depth down to a point corresponding to the range of the particles of the flux maximum. What cannot be seen intuitively in this transition is that, for the particular spectral configuration of the galactic radiation, an actual initial increase of absorbed dose accompanies this change. In other words, though the residual primary flux decreases, its absorbed dose increases. One could call this a pseudo build-up since it is not caused by production of secondaries.

With regard to the transition of the LET distribution itself, it exhibits, for the incident beam as well as at all depths, a steep negative slope from the minimum LET to the close vicinity of the narrow "spike" due to the energy dissipation in the Bragg peak at maximum LET. As the beam penetrates more deeply into the shielding or target material the steepness of the slope lessens, yet in such a way that the energy dissipation at very high LET values increases substantially whereas in a small section in the vicinity of the minimum LET it decreases.

The details of the transition are much more easily comprehended with the aid of a graphical presentation. The data will be presented in a paper to the Annual Meeting of the American Nuclear Society on June 12. A Research Report presenting the results in full detail is in preparation. The text will also appear in a special document, SD-5, of the American Nuclear Society Shielding Division.

The important implications of the findings bear upon the problem of the microbeam effectiveness of heavy nuclei. The indicated substantial increase of the LET spectrum at high and very high values toward greater depth in the target means that maximum fluxes of "microbeams" will prevail, in any experimental design, behind a well-defined optimum shield thickness which is numerically different for each Z component. Optimum moderator thicknesses vary from 12 g/cm^2 for the C group ($Z = 6$ to 9) to 6 g/cm^2 for the Ne group ($Z = 10$ to 19) and finally to 3.5 g/cm^2 for the Ca group ($Z = 20$ to 28). A basic difficulty in such experimentation with the microbeam portion of the heavy galactic spectrum rests in the fact that the flux of high LET representing the microbeams always is accompanied by the general background of all other primary and secondary components. This makes it quite a problem to identify what part of an observed biological effect is to be ascribed to the microbeams. The situation is similar to the one in the early years of the Manhatten project when, in the study of the biological effects of neutrons, it was quite difficult to produce a neutron radiation field not contaminated with gamma rays.

The program for the continuation of the study calls for extension of the analysis to other components of the heavy spectrum (the C group, $Z = 6$ to 9 and the Ca group, $Z = 20$ to 28). Since the data acquired for the Ne group indicate that the position of the flux maximum depends quite sensitively on Z, it appears desirable to split off an additional group for $Z = 26$ to 28 which might be called the Fe group. Since Fe nuclei are still fairly abundant, interest is bound to center on this group for studying local cellular damage. It therefore seems useful to define optimum conditions for experimental design closely.

Since the unfinished part of the program is rather large, a close estimate of the time requirement is difficult. As was done in the past, partial results will be published at four to five months intervals as they become available.